

# NCP623

## Ultra Low Noise 150 mA Low Dropout Voltage Regulator with ON/OFF Control

Housed in a Micro8™ or QFN6 package, the NCP623 delivers up to 150 mA where it exhibits a typical 180 mV dropout. With an incredible noise level of 25  $\mu$ V<sub>RMS</sub> (over 100 Hz to 100 kHz, with a 10 nF bypass capacitor), the NCP623 represents the ideal choice for sensitive circuits, especially in portable applications where noise performance and space are premium. The NCP623 also excels in response time and reacts in less than 25  $\mu$ s when receiving an OFF to ON signal (with no bypass capacitor).

Due to a novel concept, the NCP623 accepts output capacitors without any restrictions regarding their Equivalent Series Resistance (ESR) thus offering an obvious versatility for immediate implementation.

With a typical DC ripple rejection better than -90 dB (-70 dB @ 1.0 kHz), it naturally shields the downstream electronics against choppy power lines.

Additionally, thermal shutdown and short-circuit protection provide the final product with a high degree of ruggedness.

### Features

- Very Low Quiescent Current 170  $\mu$ A (ON, no load), 100 nA (OFF, no load)
- Very Low Dropout Voltage, Typical Value is 137 mV at an Output Current of 100 mA
- Very Low Noise with External Bypass Capacitor (10 nF), Typically 25  $\mu$ V<sub>RMS</sub> over 100 Hz to 100 kHz
- Internal Thermal Shutdown
- Extremely Tight Line Regulation Typically -90 dB
- Ripple Rejection -70 dB @ 1.0 kHz
- Line Transient Response: 1.0 mV for  $\Delta V_{in} = 3.0$  V
- Extremely Tight Load Regulation, Typically 20 mV at  $\Delta I_{out} = 150$  mA
- Multiple Output Voltages Available
- Logic Level ON/OFF Control (TTL-CMOS Compatible)
- ESR can vary from 0 to 3.0  $\Omega$

### Applications

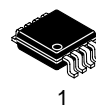
- All Portable Systems, Battery Powered Systems, Cellular Telephones, Radio Control Systems, Toys and Low Voltage Systems



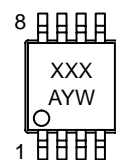
ON Semiconductor®

<http://onsemi.com>

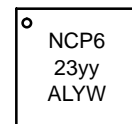
### MARKING DIAGRAMS



Micro8  
DM SUFFIX  
CASE 846A

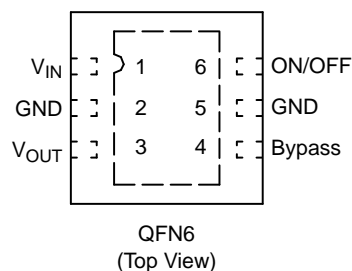
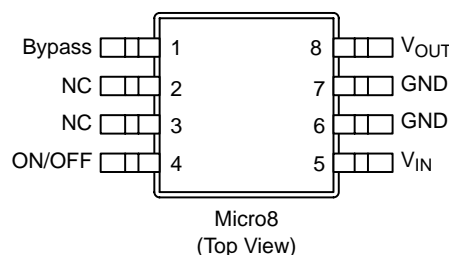


QFN6, 3X3  
MN SUFFIX  
CASE 488AE



XXX = Specific Device Code  
yy = Voltage Option  
A = Assembly Location  
L = Wafer Lot  
Y = Year  
W = Work Week

### PIN CONNECTIONS



### ORDERING INFORMATION

See detailed ordering and shipping information on page 12 of this data sheet.

# NCP623

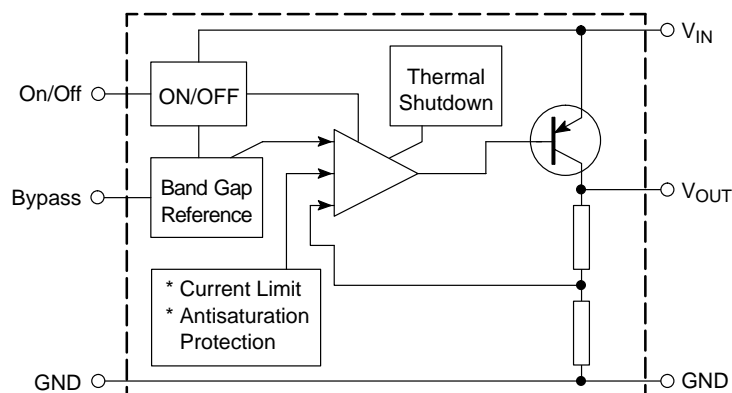


Figure 1. NCP623 Block Diagram

## MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Supply Voltage	$V_{IN}$	12	V
Power Dissipation and Thermal Resistance			
Maximum Power Dissipation	$P_D$	Internally Limited	W
Case 488AE (QFN6, 3x3) MN Suffix			°C/W
Thermal Resistance, Junction-to-Air	$R_{\theta JA}$	161	
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$	19	
Case 846A (Micro8) DM Suffix			
Thermal Resistance, Junction-to-Air	$R_{\theta JA}$	240	
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$	105	
Operating Ambient Temperature Range	$T_A$	-40 to +85	°C
Maximum Junction Temperature	$T_{Jmax}$	150	°C
Storage Temperature Range	$T_{stg}$	-60 to +150	°C
ESD Protection – Human Body Model	$V_{ESD}$	2000	V
Machine Model		200	

Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.

# NCP623

## ELECTRICAL CHARACTERISTICS (For typical values $T_A = 25^\circ\text{C}$ , for min/max values $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ , Max $T_J = 150^\circ\text{C}$ )

Characteristics	Symbol	Min	Typ	Max	Unit
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### CONTROL ELECTRICAL CHARACTERISTICS

Input Voltage Range	$V_{ON/OFF}$	0	–	$V_{in}$	V
ON/OFF Input Current (All versions) $V_{ON/OFF} = 2.4\text{ V}$	$I_{ON/OFF}$	–	2.5	–	$\mu\text{A}$
ON/OFF Input Voltages (All versions) Logic “0”, i.e. OFF State Logic “1”, i.e. ON State	$V_{ON/OFF}$	– 2.2	– –	0.3 –	V

### CURRENTS PARAMETERS

Current Consumption in OFF State (All versions) OFF Mode Current: $V_{in} = V_{out} + 1.0\text{ V}$ , $I_{out} = 0\text{ mA}$	$I_{QOFF}$	–	0.1	2.0	$\mu\text{A}$
Current Consumption in ON State (All versions) ON Mode Sat Current: $V_{in} = V_{out} + 1.0\text{ V}$ , $I_{out} = 0\text{ mA}$	$I_{QON}$	–	170	200	$\mu\text{A}$
Current Consumption in Saturation ON State (All versions) ON Mode Sat Current: $V_{in} = V_{out} - 0.5\text{ V}$ , $I_{out} = 0\text{ mA}$	$I_{QSAT}$	–	900	1400	$\mu\text{A}$
Current Limit $V_{in} = V_{out} + 1.0\text{ V}$ , (All versions) Output Short-circuited (Note 1)	$I_{MAX}$	175	210	–	mA
$V_{in} = V_{out} + 1.0\text{ V}$ , $T_A = 25^\circ\text{C}$ , $1.0\text{ mA} < I_{out} < 150\text{ mA}$ 3.3 Suffix 4.0 Suffix 5.0 Suffix	$V_{out}$	3.23 3.92 4.90	3.3 4.0 5.0	3.37 4.08 5.1	V
$V_{in} = V_{out} + 1.0\text{ V}$ , $-40^\circ\text{C} < T_A < 85^\circ\text{C}$ 3.3 Suffix 4.0 Suffix 5.0 Suffix	$V_{out}$	3.18 3.86 4.83	3.3 4.0 5.0	3.42 4.14 5.17	V

### LINE AND LOAD REGULATION, DROPOUT VOLTAGES

Line Regulation (All versions) $V_{out} + 1.0\text{ V} < V_{in} < 12\text{ V}$ , $I_{out} = 60\text{ mA}$	$Reg_{line}$	–	2.0	10	mV
Load Regulation (All versions) $V_{in} = V_{out} + 1.0\text{ V}$ $I_{out} = 1.0\text{ to }60\text{ mA}$ $I_{out} = 1.0\text{ to }100\text{ mA}$ $I_{out} = 1.0\text{ to }150\text{ mA}$	$Reg_{load}$	– – –	8.0 15 20	25 35 45	mV
Dropout Voltage (All versions) $I_{out} = 10\text{ mA}$ $I_{out} = 100\text{ mA}$ $I_{out} = 150\text{ mA}$	$V_{in} - V_{out}$	– – –	30 137 180	90 230 260	mV

### DYNAMIC PARAMETERS

Ripple Rejection (All versions) $V_{in} = V_{out} + 1.0\text{ V}$ , $V_{pp} = 1.0\text{ V}$ , $f = 1.0\text{ kHz}$ , $I_{out} = 60\text{ mA}$		60	70	–	dB
Line Transient Response $V_{in} = V_{out} + 1.0\text{ V}$ to $V_{out} + 4.0\text{ V}$ , $I_{out} = 60\text{ mA}$ , $d(V_{in})/dt = 15\text{ mV}/\mu\text{s}$		–	1.0	–	mV
Output Noise Voltage (All versions) $C_{out} = 1.0\text{ }\mu\text{F}$ , $I_{out} = 60\text{ mA}$ , $f = 100\text{ Hz to }100\text{ kHz}$ $C_{bypass} = 10\text{ nF}$ $C_{bypass} = 1.0\text{ nF}$ $C_{bypass} = 0\text{ nF}$	$V_{RMS}$	– – –	25 40 65	– – –	$\mu\text{V}_{rms}$
Output Noise Density $C_{out} = 1.0\text{ }\mu\text{F}$ , $I_{out} = 60\text{ mA}$ , $f = 1.0\text{ kHz}$	$V_N$	–	230	–	nV/ $\sqrt{\text{Hz}}$
Output Rise Time (All versions) $C_{out} = 1.0\text{ }\mu\text{F}$ , $I_{out} = 30\text{ mA}$ , $V_{ON/OFF} = 0\text{ to }2.4\text{ V}$ 1% of ON/OFF Signal to 99% of Nominal Output Voltage Without Bypass Capacitor With $C_{bypass} = 10\text{ nF}$	$t_r$	– –	40 1.1	– –	$\mu\text{s}$ ms

### THERMAL SHUTDOWN

Thermal Shutdown (All versions)		–	150	–	$^\circ\text{C}$
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1.  $I_{out}$  (Output Current) is the measured current when the output voltage drops below 0.3 V with respect to  $V_{out}$  at  $I_{out} = 30\text{ mA}$ .

## DEFINITIONS

**Load Regulation** – The change in output voltage for a change in load current at constant chip temperature.

**Dropout Voltage** – The input/output differential at which the regulator output no longer maintains regulation against further reductions in input voltage. Measured when the output drops 100 mV below its nominal value (which is measured at 1.0 V differential), dropout voltage is affected by junction temperature, load current and minimum input supply requirements.

**Output Noise Voltage** – The RMS AC voltage at the output with a constant load and no input ripple, measured over a specified frequency range.

**Maximum Power Dissipation** – The maximum total dissipation for which the regulator will operate within specifications.

**Quiescent Current** – Current which is used to operate the regulator chip and is not delivered to the load.

**Line Regulation** – The change in input voltage for a change in the input voltage. The measurement is made under conditions of low dissipation or by using pulse techniques such that the average chip temperature is not significantly affected.

**Line Transient Response** – Typical over- and undershoot response when input voltage is excited with a given slope.

**Thermal Protection** – Internal thermal shutdown circuitry is provided to protect the integrated circuit in the event that the maximum junction temperature is exceeded. When activated, typically 150°C, the regulator turns off. This feature is provided to prevent catastrophic failures from accidental overheating.

**Maximum Package Power Dissipation** – The maximum package power dissipation is the power dissipation level at which the junction temperature reaches its maximum value i.e. 125°C. The junction temperature is rising while the difference between the input power ( $V_{CC} \times I_{CC}$ ) and the output power ( $V_{out} \times I_{out}$ ) is increasing.

Depending on ambient temperature, it is possible to calculate the maximum power dissipation, maximum load current or maximum input voltage (see Application Hints: Protection).

The maximum power dissipation supported by the device is a lot increased when using appropriate application design. Mounting pad configuration on the PCB, the board material and also the ambient temperature are affected the rate of temperature rise. It means that when the  $I_C$  has good thermal conductivity through PCB, the junction temperature will be “low” even if the power dissipation is great.

The thermal resistance of the whole circuit can be evaluated by deliberately activating the thermal shutdown of the circuit (by increasing the output current or raising the input voltage for example).

Then you can calculate the power dissipation by subtracting the output power from the input power. All variables are then well known: power dissipation, thermal shutdown temperature (150°C for NCP623) and ambient temperature.

## APPLICATION HINTS

**Input Decoupling** – As with any regulator, it is necessary to reduce the dynamic impedance of the supply rail that feeds the component. A 1.0  $\mu\text{F}$  capacitor either ceramic or tantalum is recommended and should be connected close to the NCP623 package. Higher values will correspondingly improve the overall line transient response.

**Output Decoupling** – Due to a novel concept, the NCP623 is a stable component and does not require any Equivalent Series Resistance (ESR) neither a minimum output current. Capacitors exhibiting ESRs ranging from a few  $\text{m}\Omega$  up to  $3.0 \Omega$  can thus safely be used. The minimum decoupling value is 1.0  $\mu\text{F}$  and can be augmented to fulfill stringent load transient requirements. The regulator accepts ceramic chip capacitors as well as tantalum devices.

**Noise Performances** – Unlike other LDOs, the NCP623 is a true low-noise regulator. With a 10 nF bypass capacitor, it typically reaches the incredible level of 25  $\mu\text{VRMS}$  overall noise between 100 Hz and 100 kHz. To give maximum insight on noise specifications, ON Semiconductor includes spectral density graphics as well as noise dependency versus bypass capacitor.

The bypass capacitor impacts the start-up phase of the NCP623 as depicted by the data-sheet curves. A typical 1.0 ms settling time is achieved with a 10 nF bypass capacitor. However, due to its low-noise architecture, the NCP623 can operate without bypass and thus offers a typical 20  $\mu\text{s}$  start-up phase. In that case, the typical output noise stays lower than 65  $\mu\text{VRMS}$  between 100 Hz – 100 kHz.

**Protections** – The NCP623 hosts several protections, conferring natural ruggedness and reliability to the products implementing the component. The output current is internally limited to a minimum of 175 mA while temperature shutdown occurs if the die heats up beyond  $150^\circ\text{C}$ . These value lets you assess the maximum differential voltage the device can sustain at a given output current before its protections come into play.

The maximum dissipation the package can handle is given by:

$$P_{\text{max}} = \frac{T_{\text{Jmax}} - T_{\text{A}}}{R_{\theta\text{JA}}}$$

If  $T_{\text{Jmax}}$  is internally limited to  $150^\circ\text{C}$ , then the NCP623 can dissipate up to 595 mW @  $25^\circ\text{C}$ .

The power dissipated by the NCP623 can be calculated from the following formula:

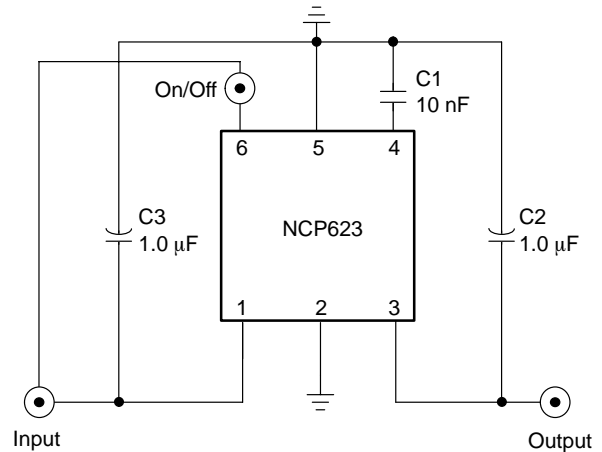
$$P_{\text{tot}} = \langle V_{\text{in}} \cdot I_{\text{gnd}}(I_{\text{out}}) \rangle + \langle V_{\text{in}} - V_{\text{out}} \rangle \cdot I_{\text{out}}$$

or

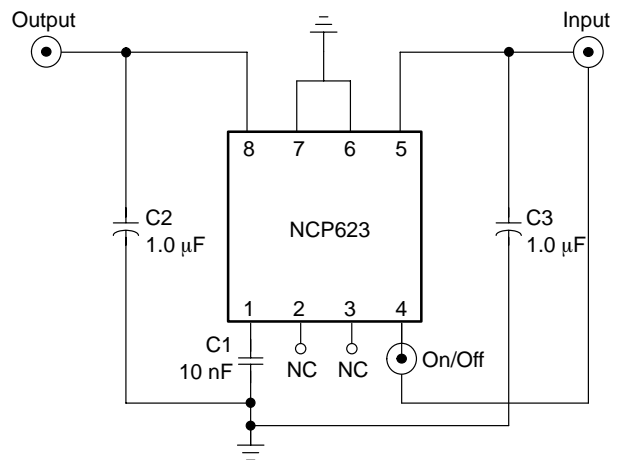
$$V_{\text{inmax}} = \frac{P_{\text{tot}} + V_{\text{out}} \cdot I_{\text{out}}}{I_{\text{gnd}} + I_{\text{out}}}$$

If a 150 mA output current is needed, the ground current is extracted from the data-sheet curves: 6.5 mA @ 150 mA. For a NCP623NW28R2 (2.8 V), the maximum input voltage will then be 6.48 V, a rather comfortable margin.

**Typical Application** – The following figure portrays the typical application for the NCP623 where both input/output decoupling capacitors appear.



**Figure 2. A Typical NCP623 Application with Recommended Capacitor Values (QFN6)**



**Figure 3. A Typical NCP623 Application with Recommended Capacitor Values (Micro8)**

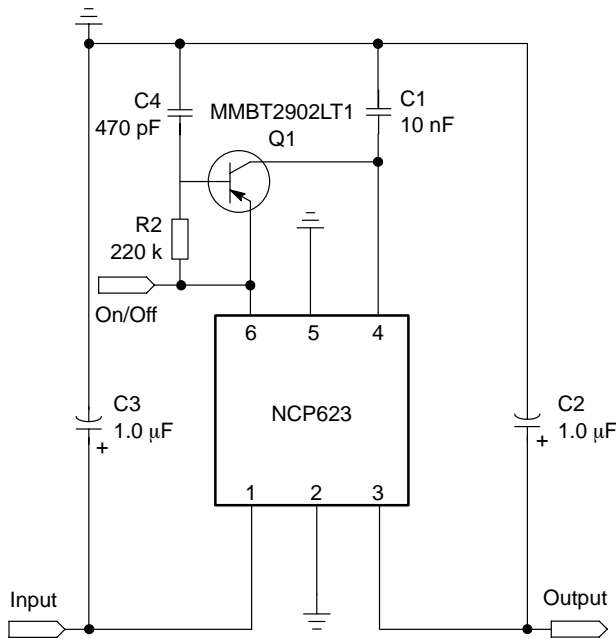
## NCP623

**NCP623 Wake-up Improvement** – In portable applications, an immediate response to an enable signal is vital. If noise is not of concern, the NCP623 without a bypass capacitor settles in nearly 20  $\mu\text{s}$  and typically delivers 65  $\mu\text{VRMS}$  between 100 Hz and 100 kHz.

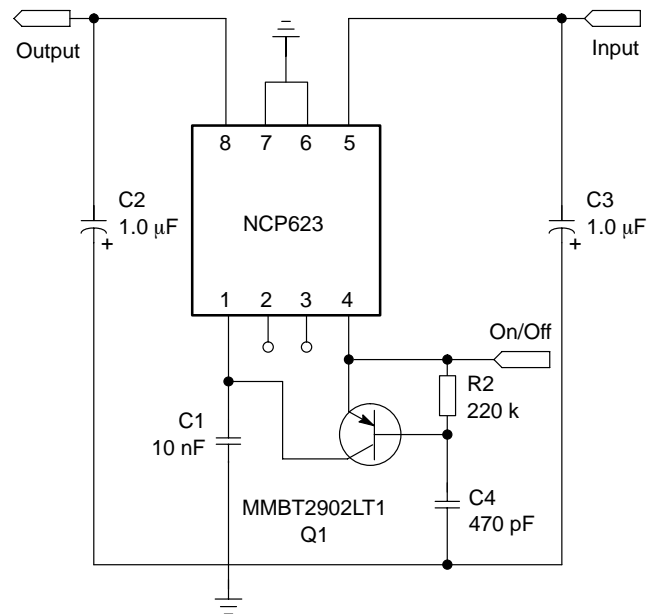
In ultra low-noise systems, the designer needs a 10 nF bypass capacitor to decrease the noise down to 25  $\mu\text{VRMS}$  between 100 Hz and 100 kHz. With the addition of the 10 nF capacitor, the wake-up time expands up to 1.0 ms as shown on the data-sheet curves. If an immediate response is wanted, following figure's circuit gives a solution to charge the bypass capacitor with the enable signal without degrading the noise response of the NCP623.

At power-on, C4 is discharged. When the control logic sends its wake-up signal by going to a high level, the PNP base is momentarily tied to ground. The PNP switch closes and immediately charges the bypass capacitor C1 toward its operating value. After a few  $\mu\text{s}$ , the PNP opens and becomes totally transparent to the regulator.

This circuit improves the response time of the regulator which drops from 1.0 ms down to 30  $\mu\text{s}$ . The value of C4 needs to be tweaked in order to avoid any bypass capacitor overload during the wake-up transient.

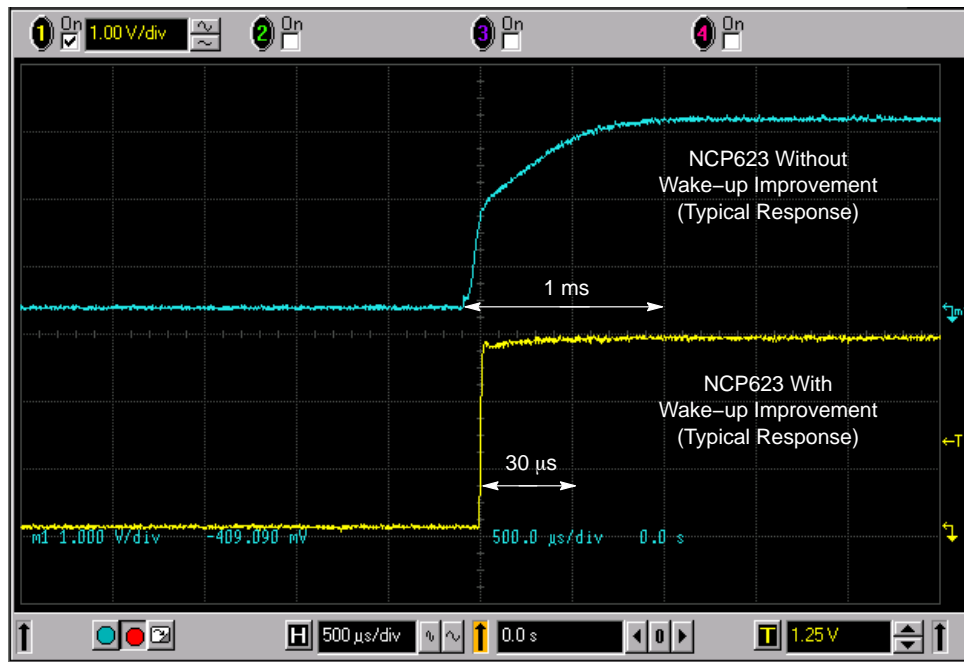


**Figure 4. A PNP Transistor Drives the Bypass Pin when Enable Goes High (QFN6)**



**Figure 5. A PNP Transistor Drives the Bypass Pin when Enable Goes High (Micro8)**

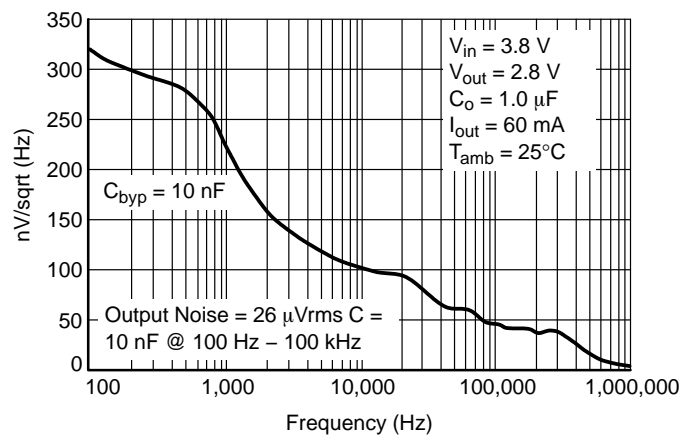
## NCP623



**Figure 6. NCP623 Wake-up Improvement with Small PNP Transistor**

The PNP being wired upon the bypass pin, it shall not degrade the noise response of the NCP623. Figure 7 confirms the good behavior of the integrated circuit in this

area which reaches a typical noise level of 26  $\mu\text{VRMS}$  (100 Hz to 100 kHz) at  $I_{\text{out}} = 60 \text{ mA}$ .



**Figure 7. Noise Density of the NCP623 with a 10 nF Bypass Capacitor and a Wake-up Improvement Network**

# TYPICAL PERFORMANCE CHARACTERISTICS

## Ground Current Performances

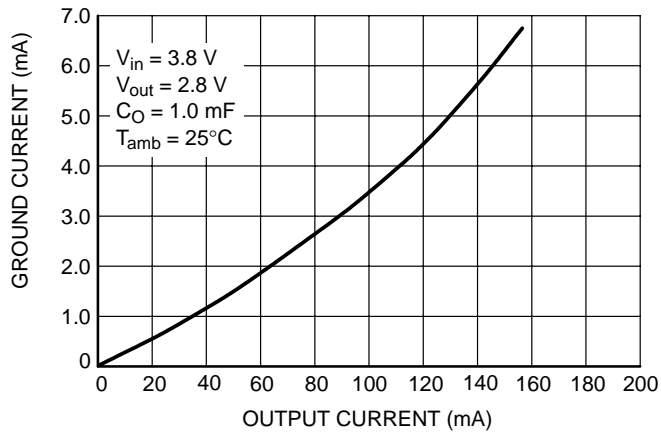


Figure 8. Ground Current versus Output Current

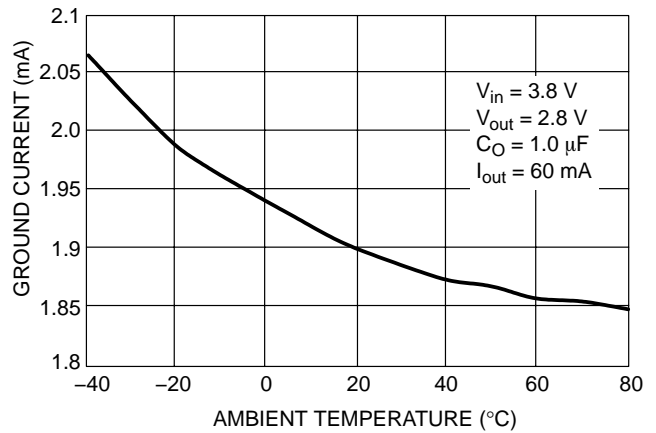


Figure 9. Ground Current versus Ambient Temperature

## Line Transient Response and Output Voltage

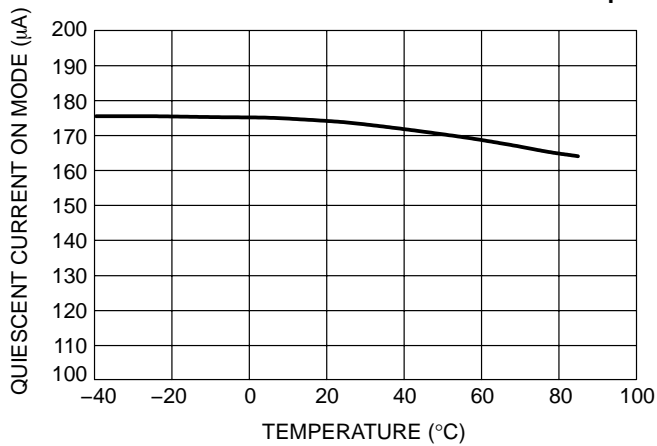


Figure 10. Quiescent Current versus Temperature

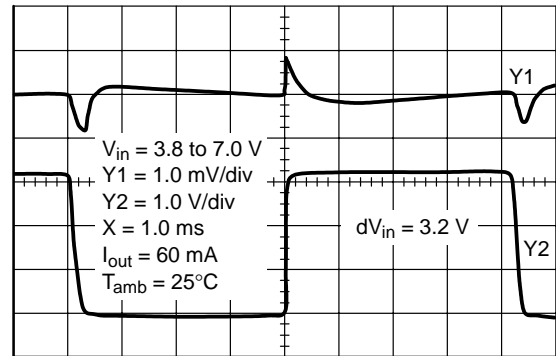
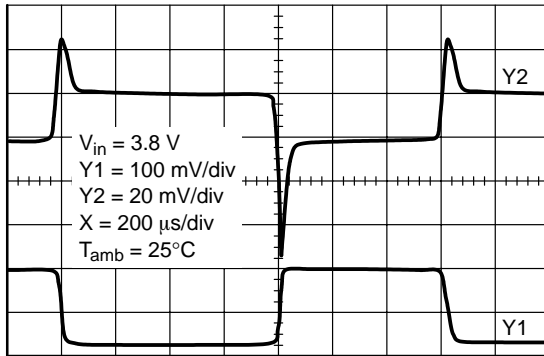


Figure 11. Line Transient Response

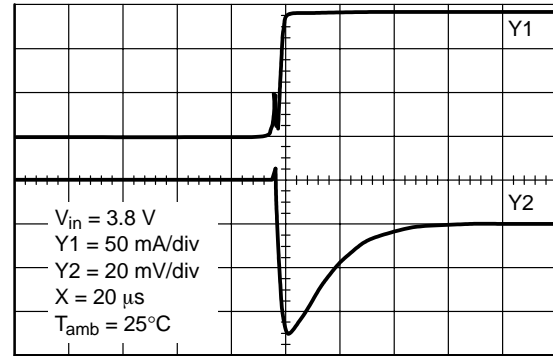


## TYPICAL PERFORMANCE CHARACTERISTICS

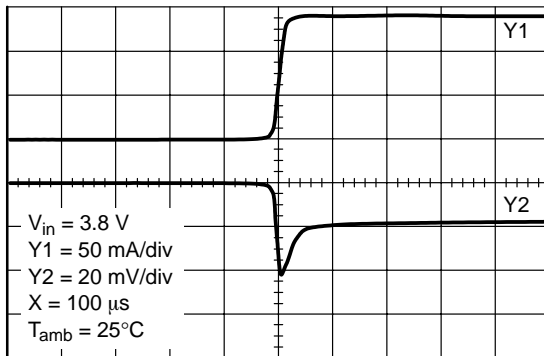
## Load Transient Response versus Load Current Slope



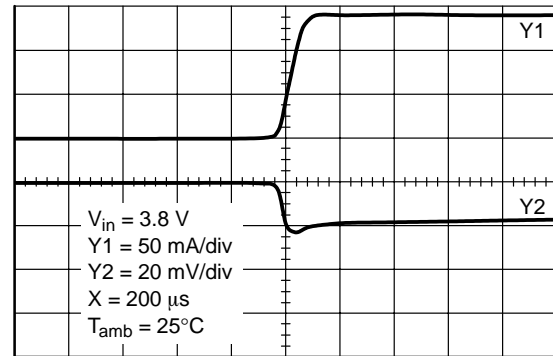
Y1: OUTPUT CURRENT, Y2: OUTPUT VOLTAGE

**Figure 12.  $I_{out} = 3.0 \text{ mA}$  to  $150 \text{ mA}$** 

Y1: OUTPUT CURRENT, Y2: OUTPUT VOLTAGE

**Figure 13.  $I_{Slope} = 100 \text{ mA}/\mu\text{s}$  (Large Scale)  
 $I_{out} = 3.0 \text{ mA}$  to  $150 \text{ mA}$** 

Y1: OUTPUT CURRENT, Y2: OUTPUT VOLTAGE

**Figure 14.  $I_{Slope} = 6.0 \text{ mA}/\mu\text{s}$  (Large Scale)  
 $I_{out} = 3.0 \text{ mA}$  to  $150 \text{ mA}$** 

Y1: OUTPUT CURRENT, Y2: OUTPUT VOLTAGE

**Figure 15.  $I_{Slope} = 2.0 \text{ mA}/\mu\text{s}$  (Large Scale)  
 $I_{out} = 3.0 \text{ mA}$  to  $150 \text{ mA}$**

# TYPICAL PERFORMANCE CHARACTERISTICS

## Noise Performances

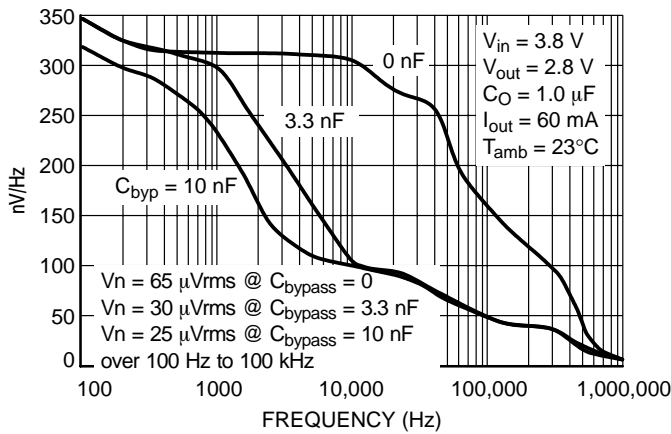


Figure 16. Noise Density versus Bypass Capacitor

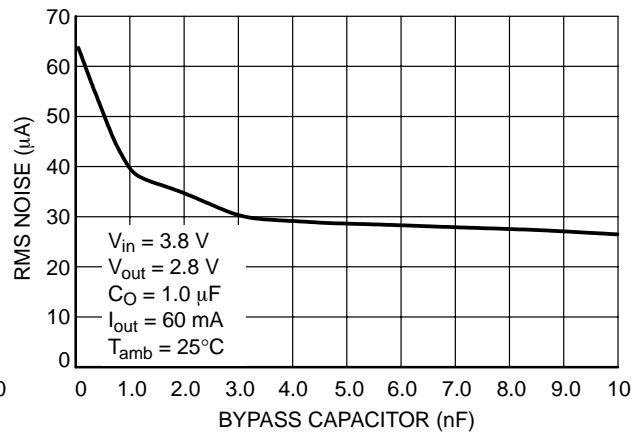


Figure 17. RMS Noise versus Bypass Capacitor (100 Hz – 100 kHz)

## Settling Time Performances

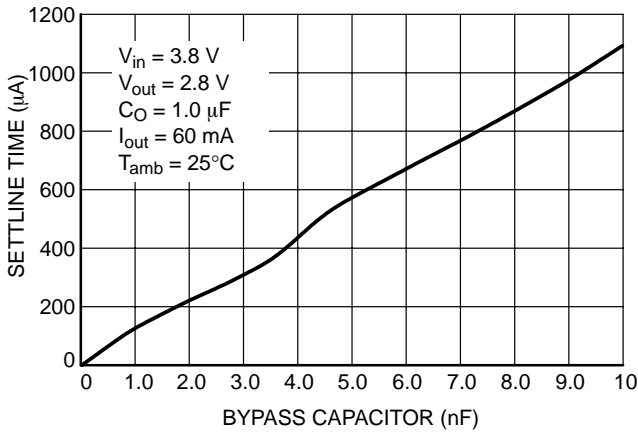


Figure 18. Output Voltage Settling Time versus Bypass Capacitor

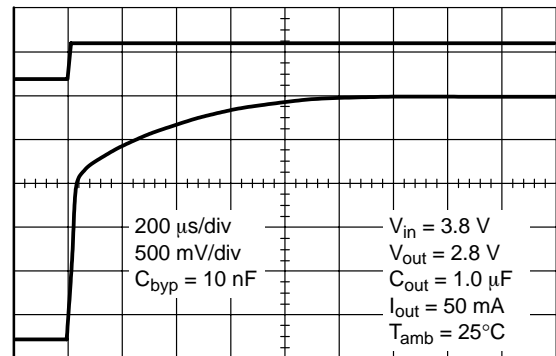


Figure 19. Output Voltage Settling Shape  $C_{bypass} = 10 \text{ nF}$

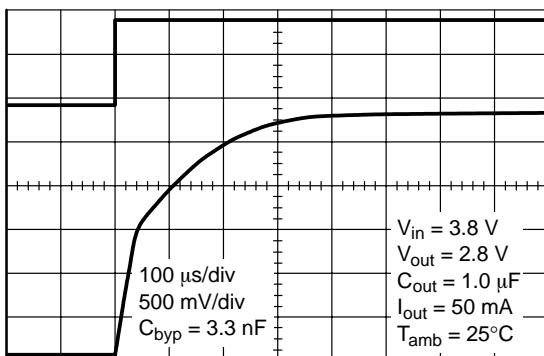


Figure 20. Output Voltage Settling Shape  $C_{bypass} = 3.3 \text{ nF}$

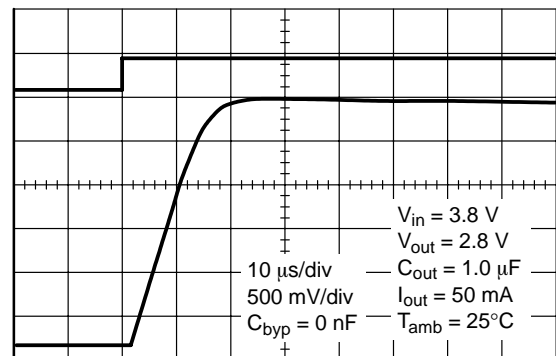


Figure 21. Output Voltage Settling Shape without Bypass Capacitor

# NCP623

## TYPICAL PERFORMANCE CHARACTERISTICS

### Dropout Voltage

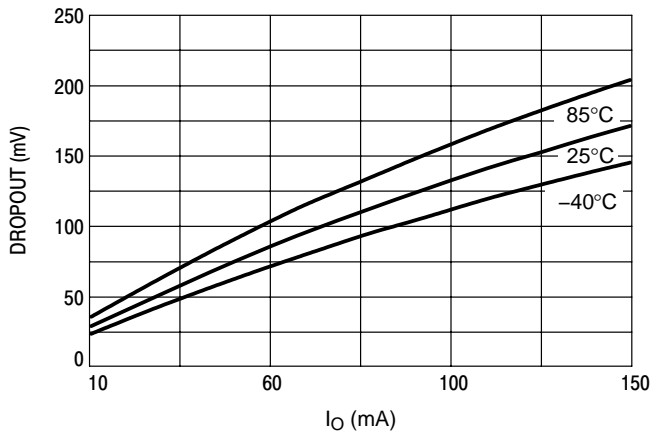


Figure 22. Dropout Voltage versus  $I_{out}$

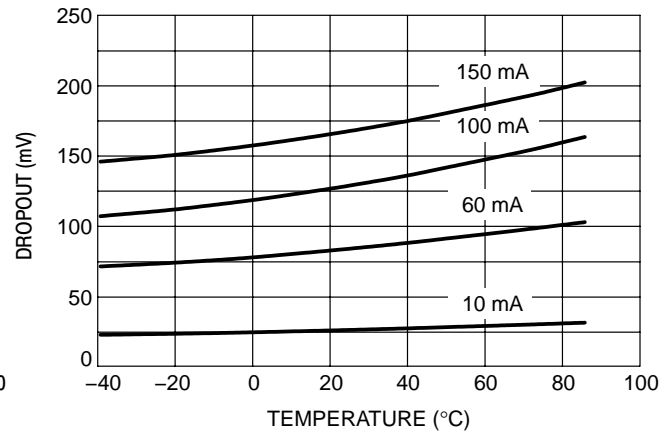


Figure 23. Dropout Voltage versus Temperature

### Output Voltage

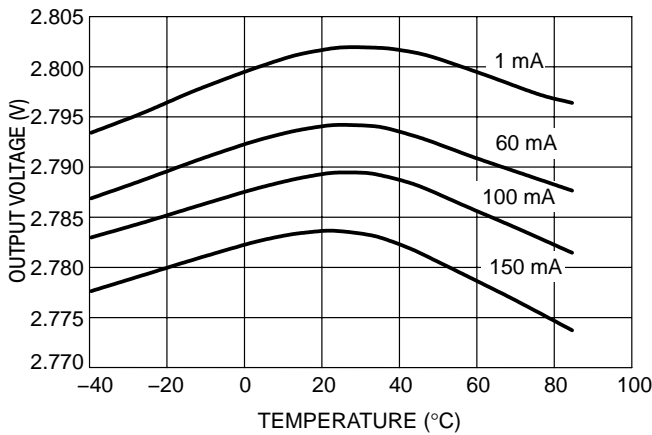


Figure 24. Output Voltage versus Temperature

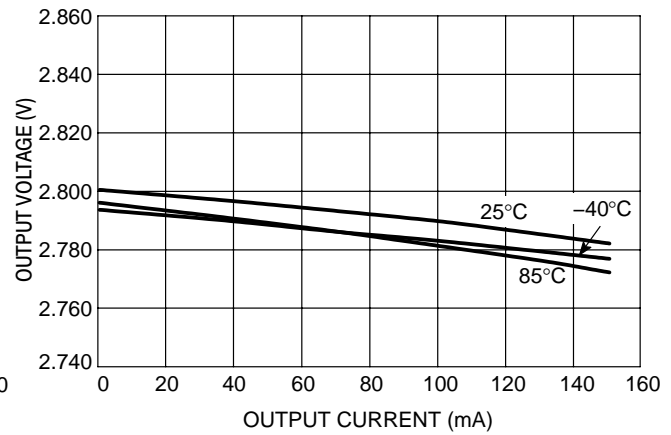


Figure 25. Output Voltage versus  $I_{out}$

### Ripple Rejection Performances

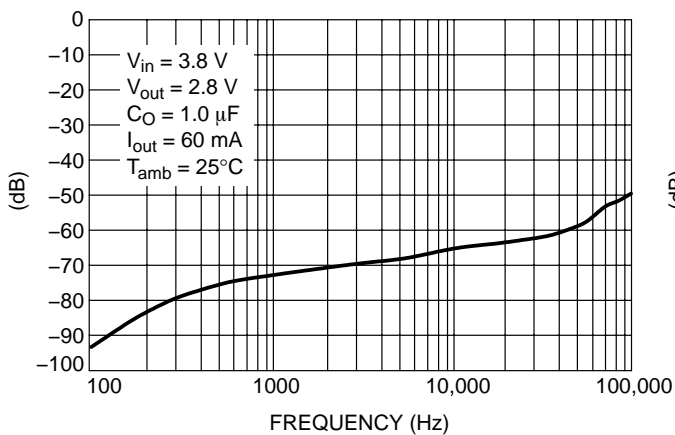


Figure 26. Ripple Rejection versus Frequency with 10 nF Bypass Capacitor

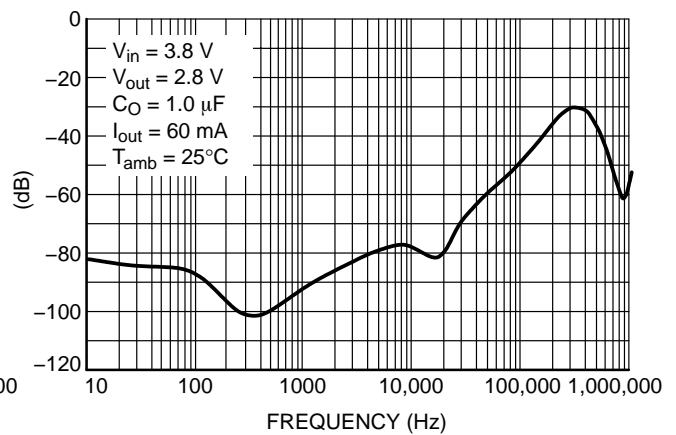


Figure 27. Ripple Rejection versus Frequency without Bypass Capacitor

## NCP623

### ORDERING INFORMATION

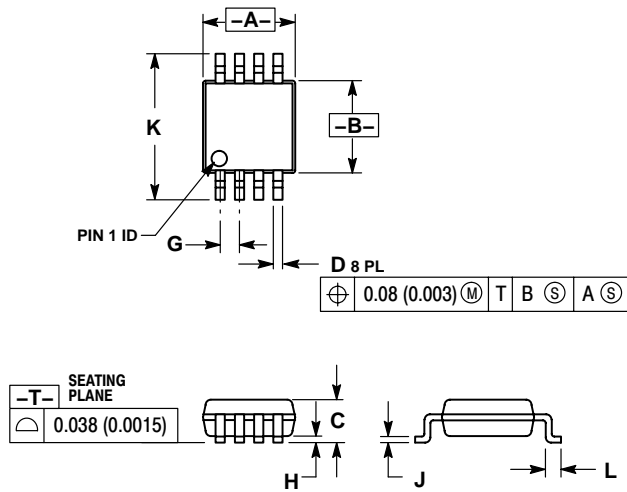
Device	Version	Package	Shipping†
NCP623DM-3.3R2	3.3 V	Micro8	4000 Tape & Reel
NCP623DM-4.0R2	4.0 V		
NCP623DM-5.0R2	5.0 V		
NCP623MN-3.3R2	3.3 V	QFN6, 3x3	3000 Tape & Reel
NCP623MN-4.0R2	4.0 V		
NCP623MN-5.0R2	5.0 V		

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

# NCP623

## PACKAGE DIMENSIONS

Micro8  
DM SUFFIX  
CASE 846A-02  
ISSUE F



### NOTES:

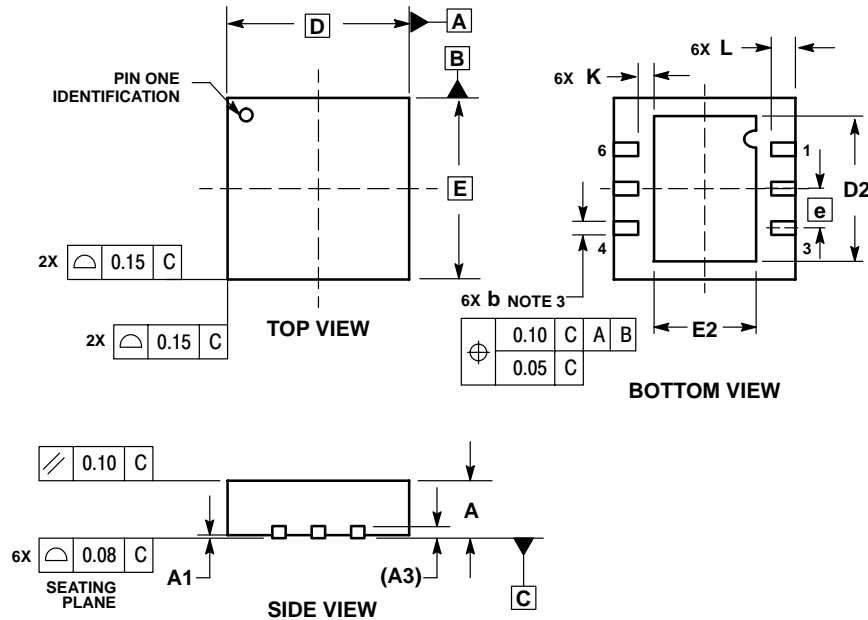
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
5. 846A-01 OBSOLETE, NEW STANDARD 846A-02.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	2.90	3.10	0.114	0.122
B	2.90	3.10	0.114	0.122
C	---	1.10	---	0.043
D	0.25	0.40	0.010	0.016
G	0.65 BSC		0.026 BSC	
H	0.05	0.15	0.002	0.006
J	0.13	0.23	0.005	0.009
K	4.75	5.05	0.187	0.199
L	0.40	0.70	0.016	0.028

# NCP623

## PACKAGE DIMENSIONS

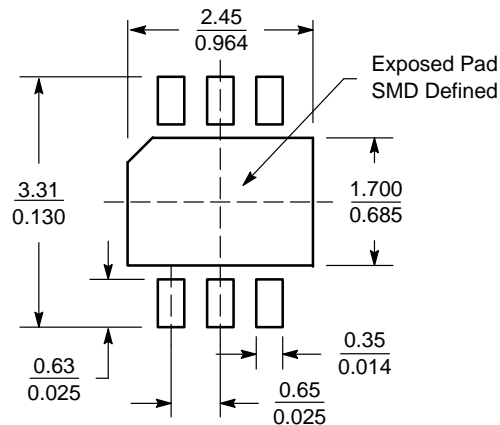
6 PIN QFN, 3x3  
MN SUFFIX  
CASE 488AE-01  
ISSUE O




### NOTES:

1. DIMENSIONS AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.25 AND 0.30 MM FROM TERMINAL.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

MILLIMETERS		
DIM	MIN	MAX
A	0.80	1.00
A1	0.00	0.05
A3	0.20	REF
b	0.18	0.30
D	3.00	BSC
D2	2.25	2.55
E	3.00	BSC
E2	1.55	1.85
e	0.65	BSC
K	0.20	---
L	0.30	0.50



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